Baseline Surveys of the Subtidal Reef Biota of the Batemans Bay Marine Park 2005-2007

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Executive Summary

Surveys of fish, invertebrates and algae were conducted on subtidal rocky reefs within the Batemans Marine Park (BMP) in December 2005 (11 sites), 2006 (25 sites) and 2007 (22 sites). At the time of the 2005 and 2006 surveys, the BMP had been created but legislation to implement the zoning scheme and hence enforce fishing restrictions was not in place. Data obtained in 2005 and 2006 thus represent baseline conditions. The zoning came into effect in June, 2007.

The BMP surveys form part of a broader study into the effectiveness of marine protected areas (MPAs) in Australian temperate waters. Surveys were undertaken with identical methodology to studies in the nearby Jervis Bay Marine Park (Barrett *et al.*, 2006) as well as in Western Australia, South Australia, Tasmania and Victoria. Surveys assessed the diversity and abundance of fish and macro-invertebrates and percentage cover estimates of algae and sessile invertebrates.

One hundred and nine species of fish, fifty five species of macro-invertebrates and seventy three species of algae were counted throughout the surveys. Schooling fish species such as *Chromis hypsilepis* (One-spot puller), *Atypichthys strigatus* (Mado sweep) and *Trachinops taeniatus* (Eastern hulafish) were the most abundant at most sites. The most abundant resident reef fish were *Parma microlepis* (white-ear), *Crinodus lophodon* (Rock cale) and *Notolabrus gymnogenis* (Crimson-banded wrasse). The most abundant invertebrates were *Centrostephanus rodgersii* (Long spine urchin), *Astralium* spp. (Turban shells), *Heliocidaris* spp. (common urchins) and *Turbo* spp. (Turbo). In many locations *C. rodgersii* were very abundant and formed extensive barrens. This most probably impacted on algal assemblages, with many sites devoid of canopy forming algae in the depth ranges (5 and 10 m) surveyed. Algae covering most substrata sampled were crustose coralline algae, species of *Peyssonnelia* (red algae) and *Ecklonia radiata* (brown kelp).

The survey methodology was designed to detect changes at all levels of species interaction and the response of sanctuary zones to protection. Ideally surveys should be repeated each year, producing a time-series of data documenting changes in the abundance and distribution of species of interest. This would also provide an indication of MPA performance as observed changes between management zones could be differentiated from chance divergence. It would also provide a reference for assessing the extent of fishing related influence on the regions subtidal reef ecosystems. Surveys of fish and mobile invertebrates should be repeated on an annual basis and surveys of algal assemblages be conducted on at least a biannual basis, until biotic changes associated with MPA protection stabilise.

Because the sites surveyed in 2005 & 2006 were deliberately different (utilising available resources to maximise sampling coverage of the BMP and sanctuary zones), the large number of sites surveyed overall meant not all could be re-surveyed in the time available in 2007. The 2007 sites therefore represent a random sample of those covered by previous surveys, and as many as could be sampled within the time and logistical constraints imposed. If there are to be ongoing annual surveys in BMP, a subset of the existing sites need to be chosen, such that they can all be reliably

repeated on an annual basis within the time frame that budgets will allow. The work to date provides a comprehensive baseline from which an ongoing program may be developed and refined within those budgetary constraints.

1. Introduction

In Australia, a core component of marine conservation planning over the past decade has been the implementation of a national, representative system of marine protected areas (NRSMPA) (ANZECC, 1999). The NRSMPA process was developed as a precautionary initiative in response to losses of inshore biodiversity at a global scale and declining confidence with traditional single-species approaches to fisheries management. As such it contributes to a movement which has seen a growing number of fully protected or "no-take" marine protected areas (MPAs) being proclaimed worldwide (Roberts and Hawkins, 2000).

The Batemans Marine Park (BMP) was announced in November 2005 as part of NSW's commitment to the NRSMPA process. Concurrent with the creation of the marine park is the need for an effective monitoring program to assess the performance of the park against management aims. Through the use of a time-series sampling design the effectiveness of various levels of protection can be distinguished from more general and coincidental long-term trends. The recommended monitoring regime consists of baseline surveys conducted prior to protection from fishing within and adjacent to proposed protection zones, followed by subsequent surveys at the same locations at biologically meaningful time intervals. Ideally, baseline surveys should be conducted over several years to assess the scale of inter-annual variability before the MPA is declared.

This report contains results of baseline surveys undertaken in the recently zoned BMP. The park is located on the south coast of New South Wales in the Batemans marine bioregion (Interim Marine and Coastal Regionalisation for Australia Technical Group, 1998) and covers 85,060 hectares of coastal and estuarine waters from Brush Island north of Batemans Bay, to Wallaga Lake south of Narooma and 3NM to sea which is the state waters limit. It includes key natural features such as the Murramarang coast, coastal lakes, the Clyde River, Batemans Bay, and the Tollgate and Montague Islands (Fig. 1).

Like all NSW marine parks BMP is zoned for multiple use. The zoning scheme encompasses five levels of protection: sanctuary zones, habitat protection zones, habitat protection zones restricted, general use zones and special purpose zones (Fig. 1). Sanctuary zones offer the highest level of protection within the marine park and prohibit all forms of fishing. Sanctuary zones cover approximately 19 % (16, 353 hectares) of the parks total area including a range of habitats from estuarine to exposed coast. Habitat protection zones (HPZ) cover 43 % of BMP and permit most recreational fishing activities but limit most commercial fishing. General use zones cover 37 % of the total park area and allow all forms of permissible recreational fishing and most forms of commercial fishing with the exception of trawling, dredging and long lining. The park also includes a number of special purpose zones (SPZ) and habitat protection zones restricted (HPZR), which provide for specific management aims. More detailed descriptions about what is permissible in each of the management zones can be found in Table 2. The BMP zoning plan came into effect in June 2007.

The surveys involved a broad based community scale underwater visual census (UVC) of shallow rocky reefs which monitors fish, large mobile invertebrates and macroalgae populations. The survey methodology collected as much information on as many species as possible with the available logistics. This methodology was designed to maximise detection of (i) changes in population numbers of heavily exploited species, (ii) cascading ecosystem effects associated with fishing, (iii) long term change and variability in reef assemblages across the region. The methodology focuses on reef systems, as these are generally the most biodiverse and heavily exploited species assemblages in inshore waters and are known to change in response to protection (Edgar and Barrett, 1999; Babcock *et al*., 1999).

The surveys covered a wide range of sites throughout the park to gain the best possible balance and replication between the zones that time, weather and depth constraints permitted (Fig. 1). The degree of replication between management zones should allow the detection of biologically significant changes in the abundance and size distribution of a wide range of species through time and between management prescriptions.

The surveys described here, follow on from previous surveys in 2005 and 2006 (Barrett et al. 2007). The 2005 survey was not designed as a comprehensive baseline, rather it was a small, one week scoping project to assess the potential of the area for a dive based monitoring program and to provide further biological information for the MPA planning phase. The second survey in 2006 was deliberately planned to compliment rather than replicate the 2005 sites, by providing a more extensive geographical coverage of the BMP and its range of sanctuary zones. Depending on the extent of inter-annual variability, the 2005 and 2006 sites could then be pooled as “before” site replicates in and ongoing study examining change from this baseline. The sites chosen for the 2007 survey were essentially a random sampling of the available pool of sites from the previous surveys, with weather and related field logistics determining which sites were sampled in the available two week survey period. They also included several additional sites chosen to provide site replication within some sanctuary zones following changes to boundaries that occurred after the 2006 survey which was based on “best guess” as to where final boundaries would be.

2. Methods

2.1 Reef monitoring protocol and its rationale

The creation of a mosaic of management zones in the seascape through the declaration of marine protected areas (MPAs) represents an ecological human exclusion experiment at a vast spatial scale (Walters and Holling, 1990). The monitoring method described below was developed to capitalise on this experiment (Edgar & Barrett, 1999). It involves underwater visual census of densities of fish, invertebrates and plants along 200 m transects at replicate sites to quantify biological changes in different management zones.

UVC techniques provide an effective technique for monitoring species at shallow-water sites in MPAs because they are non-destructive and permit the collection of large amounts of data on a broad range of species within a short period. MPA monitoring programs need to cover a range of taxa because, in addition to heavily-exploited species that are predicted to recover in new MPAs, significant secondary effects of fishing may occur that would otherwise go undetected.

Sites locations are fixed between surveys, with sampling repeated in the same month in different years to minimise seasonal effects. The 200 m transect distance is subdivided into four contiguous 50 m long blocks, each of which is 10 m wide for censuses of mobile fish and 1 m wide for mobile macro-invertebrates and cryptic fish. Five quadrat positions per 50 meter block set at 10 m intervals are used to sample algae, sessile invertebrates and some measurements of substrata.

This ‘extended-transect’ sampling design was selected to maximise the amount of information gathered at each site by four divers (two buddy pairs), each with a single tank of air. Three sites can be surveyed per day, weather conditions permitting. Pilot trials indicated that if divers reduced the amount of information collected per site to increase transect replication, for example by surveying two rather than four 50 m long blocks, then with the same logistical constraints, site coverage would not have increased greatly because of the lengthy time required to move between sites (pull anchor, gear up for diving, set transect lines). Alternatively collection of additional information at each site would require either more dive personnel or reduced site coverage.

The overriding consideration when planning the monitoring design was that temporal change in protected zones provided the primary focus of study. Consequently, spatial variation at the site level that interferes within the detection of the temporal signal was minimised as much as possible. This was done by not only censusing fixed sites through time and in the same season each years but also by surveying along set depth contours and aggregating data over a long distance (200 m) per site to smooth fine scale variation.

The collection of data from four 50 m long blocks is best viewed as an approach to increase the precision of estimates of mean values for a 50 m block at a site. Information on spatial substructure within sites – in the form of data from the four contiguous 50 m-long transects – was not obtained to assess variance within sites. Rather the 200 m transect was subdivided into four blocks because:

1. Data are more easily compared with results of other investigators, who often use transect lengths of 50 m.
2. Different divers can collect information in different 50 m sections of the 200 m length, allowing equitable distribution of dive time regardless of number of divers, and permitting analysis of between-diver effects.
3. If greater precision at a site is required, for example if rock lobster numbers are highly spatially-variable but are of great interest, then extra 50-m blocks can be added. Similarly, the number of 50-m blocks can be reduced if dive time is limited, such as when surveying deep sites. In both cases, data at the 50-m block scale remain directly comparable with data for other sites.
4. Site data can be partitioned to allow inter-site comparisons of particular habitat types. For example, if the quadrant data indicates that a sea urchin barren extends for the first 70 m of a transect followed by 130 m of *Sargassum*, then the first 50 m block provides data on species assemblages in sea urchin barrens, the second 50 m block data on ecotonal zones, and the third and fourth blocks data on fucoid algal habitats. Differences in effects of MPA protection in urchin barrens versus algal habitat can be assessed using these data.

The extended-transect design represents a compromise between power and generality, lying intermediate along the spectrum from more general site studies that involve random replicate transects at each site, and more powerful studies with a single fixed-transect permanently attached to the seabed.

The extended-transect design is considerably more powerful than a random-transect design, but with less generality in associated statistical tests. Although an understanding of within-site variation can be critical for studies with other aims, individual sites had no intrinsic importance in this MPA study. Our interest was focused on within- and between-zone effects, with sites providing replicate information for analyses. Advantages of random-transect methods over our method are: (i) sites encompass a greater total area of seabed because a range of depths are surveyed at each site rather than a single depth contour, increasing generality, and (ii) information is gathered on spatial variance within sites. However, for a study of MPA effects, we considered that these advantages were greatly outweighed by disadvantages. These include: (i) spatial noise associated with randomised placement of transects that obscures the fundamental temporal signal, (ii) lost diving time during periods when divers move to the start of different replicate transects, resulting in reduced data collection per site, (iii) difficulties in truly randomising transect placement, and spatial biases associated with haphazard placement, and (iv) confounding with depth as a consequence of some sites being relatively flat with little depth range, and others being steeply-sloping and encompassing a large depth range. In particular as species vary strongly with depth it is better to included this as an explicit variable within analyses rather than contributing to spatial noise between replicates (Kingsford, 1998).

A design involving transects that are permanently attached to the seabed would be more powerful at detecting temporal effects than our design, but at some minor cost in generality and at considerable extra cost in dive time and instalment. The cost in generality for a physically-fixed transect design relates to the fact that our transects were relocated on each sampling event within a band that extended ca. 1 m in depth (due in large part to different tidal heights at the time of each survey) and ca. 20 m in horizontal extent (due to imprecision in site relocation). Thus, some spatial ‘noise’ is added to the temporal ‘signal’ in our design, reducing power but also reducing the possibility that overall conclusions are affected by anomalous positioning of a transect.

However there were two major reasons for not utilising a physically-fixed transect. Firstly, we recognised aesthetic values associated with diving in MPAs, and considered that 200 m long ropes or chains permanently attached to the seabed in sanctuary zones, or permanent star picket markers, would represent a visual intrusion to recreational divers. The presence of a permanent transect line, including wave-induced movement that abrades plants and attraction of divers, could also potentially affect the habitat and thus the ecosystem components censused along the transect.

Secondly, despite the theoretical increase in power to detect temporal signal for physically-fixed transect designs, power is adversely affected in a practical sense by reduced replication. Considerable dive time is required initially to set up permanent transect lines and seabed markers. If transect lines are left attached between surveys, then they need maintenance, perhaps with replacement after two or three years. If lines are strung on each survey between permanent markers such as star pickets, then dive time is reduced by the extra time required to set the line after locating markers, some of which may disappear between annual surveys.

2.2 Sites

This report presents results from surveys conducted in December 2005, 2006 and 2007. In 2005, 11 sites were surveyed: 7 at 5 m depths and 4 at 10 m depths. In 2006, 25 different sites were surveyed: 15 at 5 m depths and 10 at 10 m depths. In 2007, 22 sites were surveyed: 14 at 5 m depths and 8 at 10 m depths (Fig. 1 and Table 1). Throughout all surveys the following zone types were sampled: sanctuary, 17; habitat protection, 12; general use, 8; special purpose, 2. For the purpose of this report, general use, habitat protected and habitat protected restricted zones have been grouped as ‘Take’ (22 sites in total) and sanctuary and special purpose zones as ‘No Take’ zones (19 sites in total). Due to the vast size of the park and the limited sampling time, sites were not revisited between 2005 and 2006. Different sites were sampled in 2006 to gather sufficient coverage across the park in order of preference over repetition of sites between years. Furthermore the final zoning scheme had not been released at the time of the 2006 survey, slightly affecting the balance of sites between zones. In 2007, a range of sites in the different zoning categories were sampled and the total number sampled was restricted by unfavourable weather conditions.

2.3 Census methodology

At each reef site the abundance and size structure of fish, the abundance of cryptic fish and large benthic invertebrates, and the percent cover of macroalgae and cover forming invertebrates were censused separately along the same 4 x 50 m transects. The transect lines were laid end to end along a fixed depth contour. Trained scuba divers, with a minimum bachelor's degree in biology, recorded all data on waterproof paper.

2.3.1 Fish

The abundance of the various fish species within 5 m of each side of the transect line were recorded by a diver swimming up the offshore side of the line and then back along the inshore side in the middle of a 5 m wide lane. Special care was taken with counts of species that were obviously attracted to the divers.

Double counting of individual fish sometimes occurred when the diver returned along the inshore side of the transect line. Nevertheless, such double counts have little importance if the inshore and offshore 50 m x 5 m blocks are considered as two separate (albeit non-independent) estimates for the 50 m transect length. The reason that fish were counted on the return leg regardless of whether they were recognised as having been counted on the initial leg was that if this had not been done then return counts would be lower than initial counts, and mean total density estimates not comparable with 50 m x 5 m density estimates of workers elsewhere. Return counts were undertaken to allow greater precision of site estimates with little extra underwater time – transect lines already having been set.

Fish census data are affected by a range of biases, including observer error and variation in behavioural responses of fish to divers (DeMartini and Roberts, 1990; Kulbicki and Sarramega, 1999; Thompson and Mapstone, 1997). Such biases have been investigated in part and discussed for the transect methods used here (Edgar *et al.*, 2004). Despite the existence of census biases, we consider them to be largely systematic and to not greatly confound interpretation of patterns because data will only be used for relative comparisons between different management zones. Care was taken to ensure that sampling effort for each diver was equitably distributed between no take and other management zone types.

2.3.2 Cryptic fish and megafaunal invertebrates

Cryptic fish and megafaunal invertebrates were surveyed by searching the seabed within a distance of 1 m from the transect line. This included all visible crevices and overhangs but not overturning boulders. Algae were swept away from the transect to obtain a clear view of the substratum. A total of 4 x 1 m x 50 m transects were surveyed at each site. Most mobile megafaunal invertebrates were counted, including large decapod crustaceans, large gastropods, bivalves, octopus and echinoderms. Invertebrates not counted were the cryptic species or those too small to be accurately counted in the time available per survey. Cryptic fish were also identified, counted and the size estimated.

2.3.3 Macroalgae

The cover of macroalgae, coral, sponges and other sessile invertebrate species was quantified by placing a grided 0.25 m^2 quadrat at 10 m intervals along the transect lines. Macroalgae cover was assessed by identifying and counting algae species that occurred directly under the 50 (49 plus one corner) grid positions. Algae were counted in layers, with percent cover of overstorey species recorded first. These were then pushed aside exposing the understorey species for counting. Unknown or unidentifiable species were assigned functional categories. A total of 5 m^2 was surveyed at each site. Some substrate classifications such ‘urchin barrens’ were also measured using this methodology.

2.4 Statistical Analysis

Similarities between sites and management zones for fish assemblages, macro-invertebrates and algae were examined graphically using non-metric multidimensional scaling (MDS). Data input to matrices for multivariate analyses were square root transformed to reduce the influence of the most abundant species, and converted to a symmetric matrix of biotic similarity between pairs of sites using the Bray-Curtis similarity index, which is relatively insensitive to data sets with many zero values. The usefulness of the two dimensional MDS display of biotic relationships is indicated by the stress statistic, which signifies a good depiction of relationships when <0.1 and poor depiction when >0.2 (Clarke, 1993).

Once several years of post MPA declaration data are available, curvilinear modelling techniques should comprise the most useful of available methods for investigating MPAs. Using non-linear regression, for example, relationships between biological response to protection and variables such as time since MPA declaration, management zone size, distance from MPA boundary, reef habitat complexity, and fishing pressure prior to declaration of the MPA can be quantified. Effect size is readily estimated as the difference between the value of a variable at any point in time and the mean of baseline values for that variable at the same site prior to MPA declaration when compared with the magnitude of changes occurring at external controls.

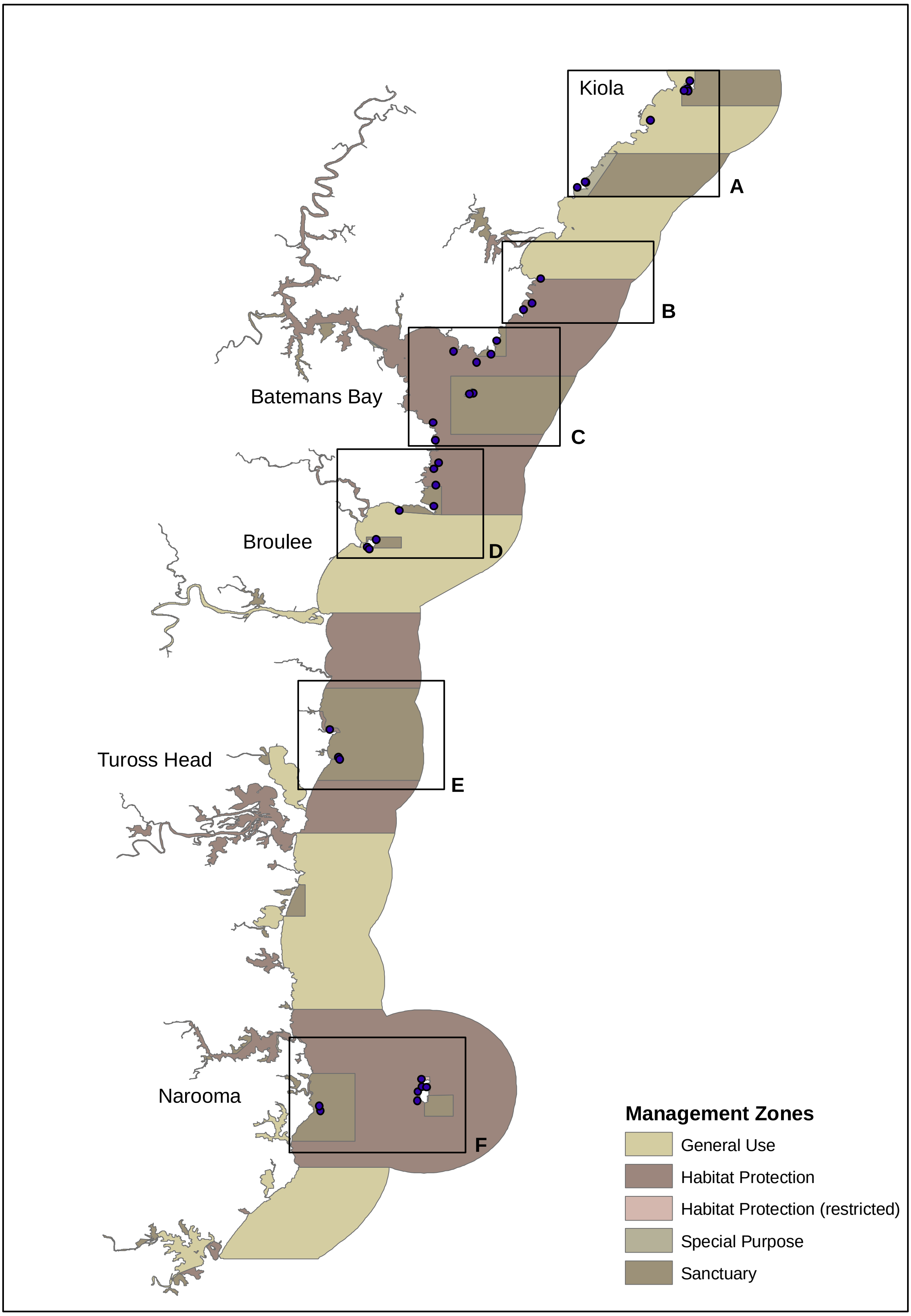

Figure 1. Index map showing location of sites surveyed in the Batemans Marine Park during surveys in 2005, 2006 and 2007.

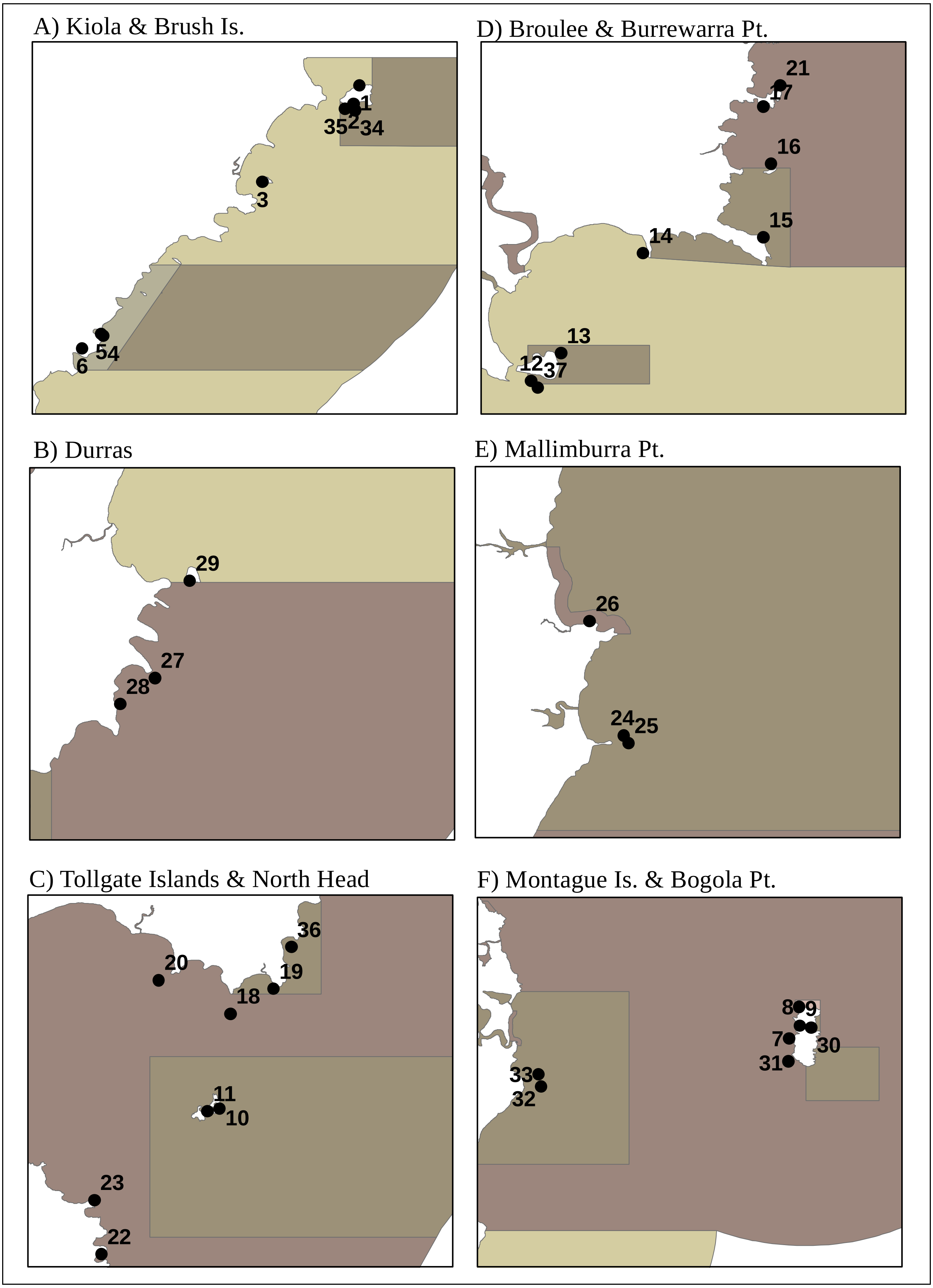

Figure 1. cont. Detailed site positions from surveys in the Batemans Marine Park during 2005, 2006 and 2007.

Table 1. Site details for surveys conducted at Batemans Bay. Positions are recorded in decimal degrees using WGS 84.

Site	Site Name	Latitude	Longitude	Depth (m)	Year	Zone Type
1	Brush Island Mid North	-35.52617	150.41713	10	2005, 2007	general use
2	Brush Island Mid South	-35.53148	150.41545	5	2005	sanctuary
3	Belowla Island SW	-35.55425	150.38897	5	2005, 2007	general use
4	Snapper Point	-35.59893	150.34278	10	2005	general use
5	Ohara Mountain Gully	-35.59845	150.34212	5	2005, 2007	special purpose
6	Kiola Gulch	-35.60529	150.33655	5	2005, 2007	special purpose
7	Montague Island mid inner	-36.25163	150.22207	10	2005	habitat protection
8	Montague Island NW Inner	-36.24802	150.22517	5	2005	habitat protection
9	Montague Island North	-36.24267	150.22492	5	2005	habitat protection (restricted)
10	Shark Gutter NE Tollgates	-35.75012	150.26204	10	2005, 2007	sanctuary
11	Tollgates - Outer Mid Bay	-35.75073	150.25915	5	2005, 2007	sanctuary
12	Broulee Island	-35.86079	150.18594	10	2006	general use
13	Broulee North	-35.85507	150.19207	5	2006, 2007	sanctuary
14	West Longnose Point	-35.83457	150.20885	5	2006	general use
15	Burrewarra Point	-35.83132	150.23347	10	2006, 2007	sanctuary
16	Jimmies Island*	-35.81623	150.23512	5	2006, 2007	sanctuary
17	Pretty Point	-35.80453	150.23347	5	2006	habitat protection
18	Yellow Rock	-35.72811	150.26449	10	2006, 2007	habitat protection
19	North Head	-35.72235	150.27453	5	2006, 2007	sanctuary
20	Acron Ledge	-35.72030	150.24789	5	2006, 2007	habitat protection
21	Pretty Point North	-35.80019	150.23690	10	2006, 2007	habitat protection
22	Garden Point	-35.78389	150.23465	5	2006, 2007	habitat protection
23	Lilly Pilly North	-35.77133	150.23295	5	2006, 2007	habitat protection
24	Bingi Bingi Point	-36.01152	150.16517	10	2006, 2007	sanctuary
25	Bingi Bingi Point	-36.01290	150.16603	5	2006, 2007	sanctuary
26	Mullimburra Point	-35.99157	150.15918	5	2006, 2007	habitat protection
27	Flat Rock South	-35.68546	150.30408	5	2006	habitat protection
28	Richmond Point	-35.69019	150.29786	5	2006	habitat protection
29	Wasp Island	-35.66796	150.31036	5	2006	general use
30	Montague Island East	-36.24850	150.22827	5,10	2006	sanctuary
31	Montague Island SW	-36.25803	150.22185	5	2006	habitat protection
32	Bogola Point	-36.26515	150.15226	10	2006	sanctuary
33	Bogola North	-36.26173	150.15152	10	2006	sanctuary
34	Brush Island South	-35.53337	150.41590	10	2006, 2007	sanctuary
35	Brush Island SW	-35.53293	150.41297	10	2006, 2007	sanctuary
36	Honeysuckle Bay*	-35.71264	150.27867	5	2007	sanctuary
37	Broulee Island South*	-35.86214	150.18729	5	2007	sanctuary

* Position is inaccurate

Table 2. Brief overview of zone categories – refer to the Batemans Zoning Plan for details.

General use zone	Most activities permitted. No commercial fishing by trawl, dredge or long line. Bag limits, size limits and seasonal closures continue to apply.
Habitat protection zone	Most recreational fishing activities permitted with some restrictions to the collection of bait. Limited commercial fishing is permitted but not trawling, seine netting, set lines or drift lines.
Habitat protection zone restricted Montague Island (site 8)	Same as the habitat protection zone with additional temporal restrictions between 1 November and 30 April each year to protect grey nurse sharks. Additional restrictions include fishing with bait, anchoring, fishing with a wire trace line, netting and fishing with spears or spearguns.
Murramarang special purpose zone (sites 4 and 6)	Recreational and most commercial fishing not permitted. Allows commercial abalone harvesting.
Sanctuary zone	All fishing prohibited

3. Results

Many of the results presented here are for the purpose of giving a general description of patterns observed between years and the two primary levels of protection. As sites and the extent of site replication varied between the three surveys because of the differing intent of each survey, the overall means between years and levels of protection will reflect that. All interpretations therefore need to be caveated with that inherent bias.

3.1 Fish

One hundred and nine species of fish were counted during the Batemans Bay surveys. The number of species present was relatively similar throughout 2005-2007 and no biologically significant differences between Take and No take zones was found (Fig. 2a), suggesting that the fish diversity within the sanctuary zones was broadly representative of the overall diversity within the area. The overall diversity was smaller but relatively similar to that found in the Jervis Bay Marine Park (Barrett *et al*., 2006), reflecting the proximal but more southerly position of the BMP. A large proportion of fish species were site specific with approximately one third of all species observed at only one site. Abundances of fish species at each site have been previously reported for 2005 and 2006 (Barrett *et al.*, 2007) and these are shown in Appendix 1 for 2007.

The total abundance of fish differed slightly among years sampled (Fig. 2b). Abundances were greater in 2005 and 2006 than in 2007, although inter-year comparisons need to be interpreted in light of the differences in sites surveyed between years, and the influence of chance encounters with large schools of pelagic species on overall total abundance estimates. The most abundant fish species were generally schooling species such as *Atypichthys strigatus* (Mado sweep), *Chromis hypsilepis* (One-spot puller), *Trachinops taeniatus* (Eastern hulafish), *Scorpis lineolata* (Silver sweep) and *Trachurus novaezelandiae* (Yellow-tail scad), with these species dominating the assemblages at many sites. Characteristic non-schooling species included resident reef fish such as *Parma microlepis* (White-ear), *Crinodus lophodon* (Rock cale), *Notolabrus gymnogenis* (Crimson-banded wrasse), *Cheilodactylus fuscus* (Red morwong), *Ophthalmolepis lineolata* (Maori wrasse), *Parma unifasciata* (Girdled parma) and *Odax cyanomelas* (Herring cale). Other species locally abundant at a few sites included *Girella elevata* (Rock blackfish), *Nototodarus gouldie* (Arrow squid) and *Threpterius maculosus* (Kelpfish).

Patterns of abundance of fish between management zones varied according to the year sampled (Fig. 2b). While this data is strongly influenced by site variation between surveys and schooling species, the overall balance between Take and No-take zones when averaged across years suggests the chosen sanctuary zones are broadly representative of overall abundance within this area. At the individual species level, the protection related patterns of abundance were varied. For the numerically abundant schooling species such as *A. strigatus* and *C. hypsileps* (Fig. 3 a-b) any pattern was obscured by year to year variability, whereas *T. taeniatus* proved an exception to this (Fig. 3c), remaining relative stability with respect to time and protection level. The resident species such as *C. lophodon*, *P. microleps* & *N. gymnogenis* (Fig. 3d-f) were predictably more stable with time, and were generally well balanced between levels of protection. Special interest species such as *Caranax dentex* (Silver trevally), *Meuschenia* spp. (Leatherjackets) and *Chrsophrys auratus* (Snapper) were either rare (in the case of Snapper), highly variable between sites (Leatherjacket species), or variable between years due to chance encounters with schools (Silver trevally) (Fig. 3 g-i).

An MDS plot of the relationship of the sites surveyed with respect to the overall fish assemblages present, indicated there were no significant differences in fish assemblages among Take and No take zones and between assemblages at 5 m and 10 m depths (Fig. 4). Sites with similar fish assemblages are closer to each other than sites with fewer similarities. The MDS depicts a relatively good overlap in the spread of sites within each level of protection. One exception is Site 1, Brush Island Mid North, which is in a general use zone and was an outlier due to unusually high species richness and abundance.

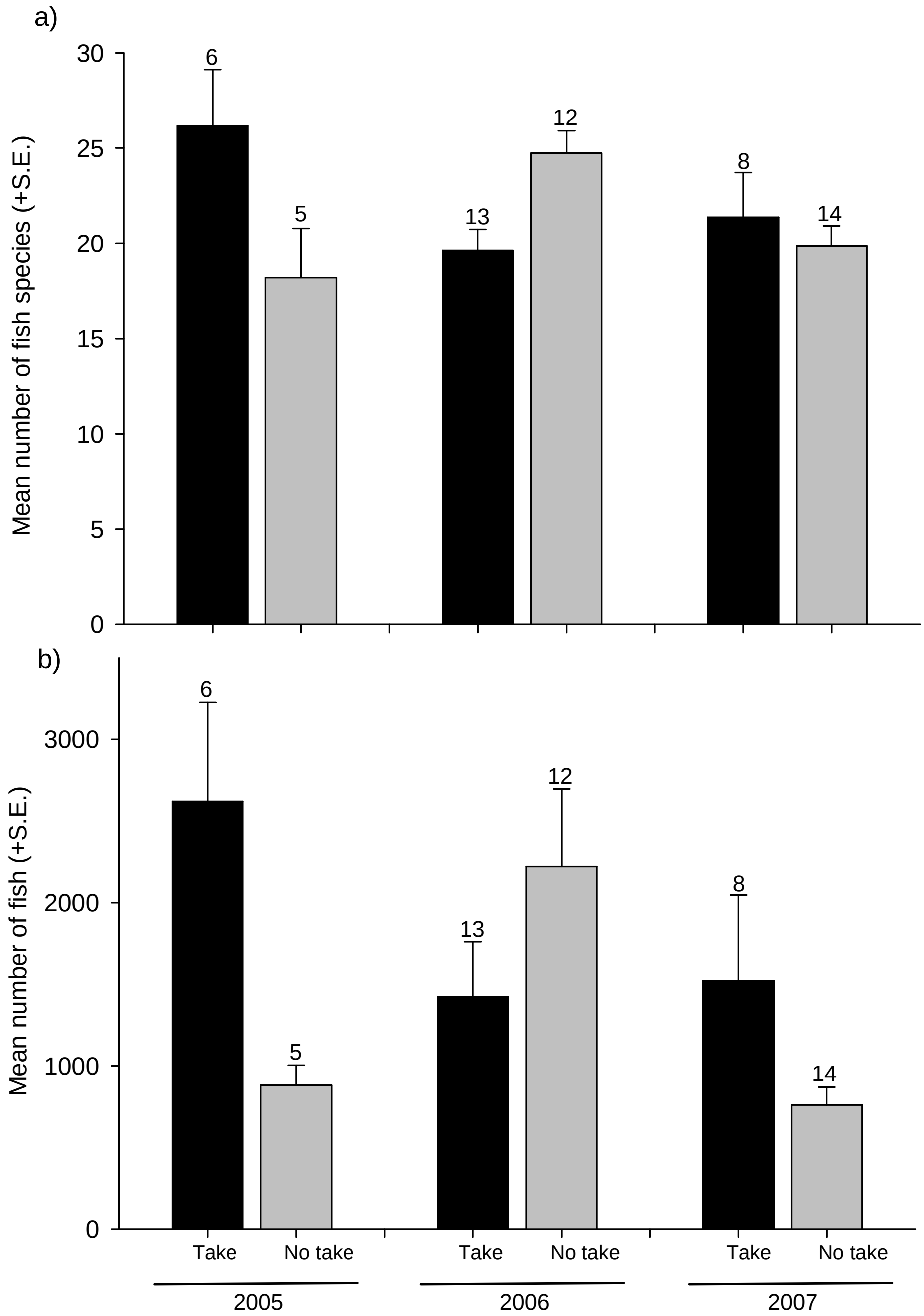

Figure 2. Mean diversity (a) and abundance (b) of fish in Batemans Marine Park, in Take (general use, habitat protection, habitat protection restricted) and No take (special purpose, sanctuary) zones. Numbers of sites sampled (n) are above each bar.

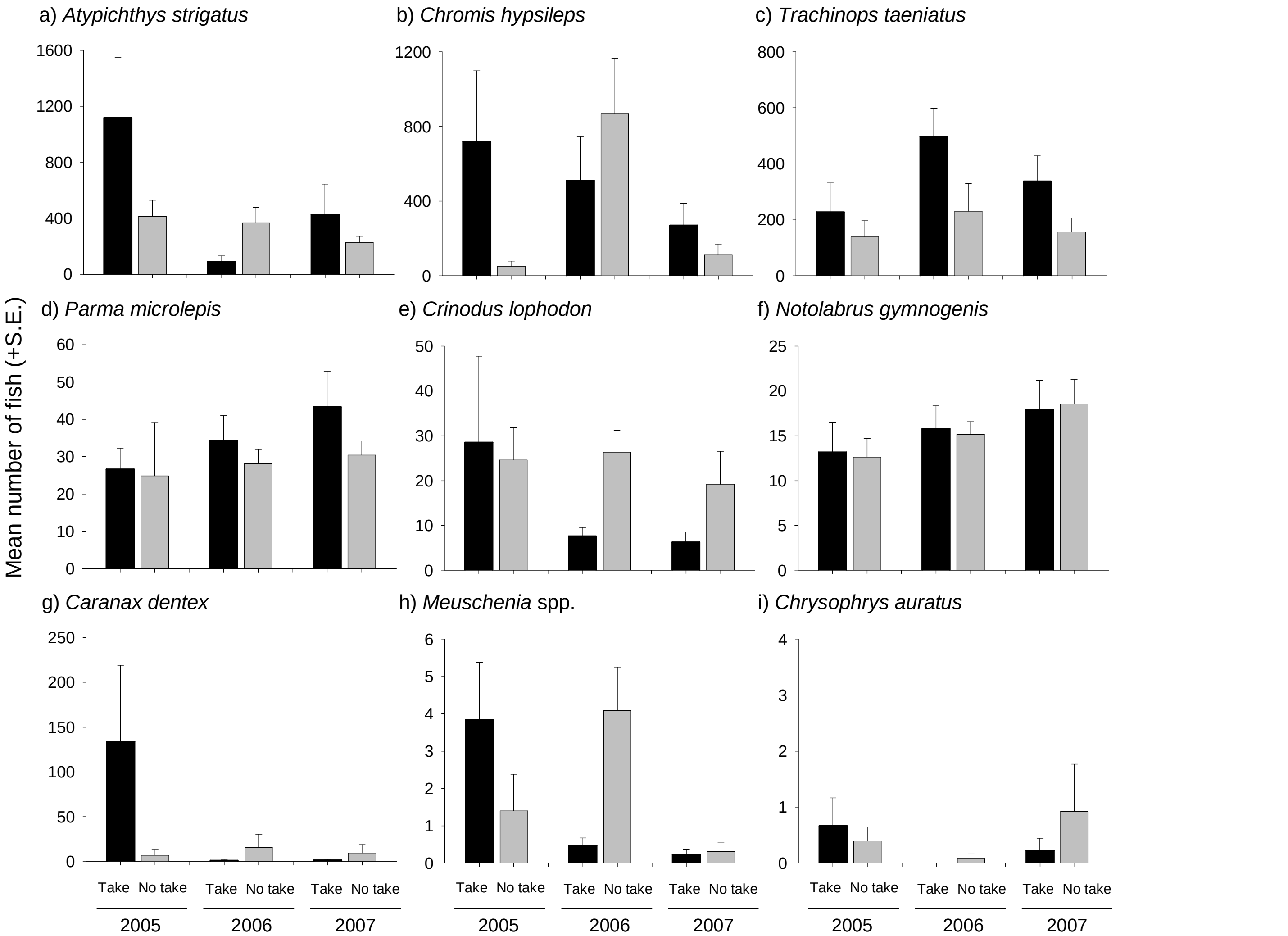

Figure 3. Mean abundance of most abundant schooling (a-c), resident (d-f) and special interest (g-i) fish in Batemans Marine Park in Take (general use, habitat protection, habitat protection restricted) and No take (special purpose, sanctuary) zones. Numbers of sites sampled are shown in Fig. 2.

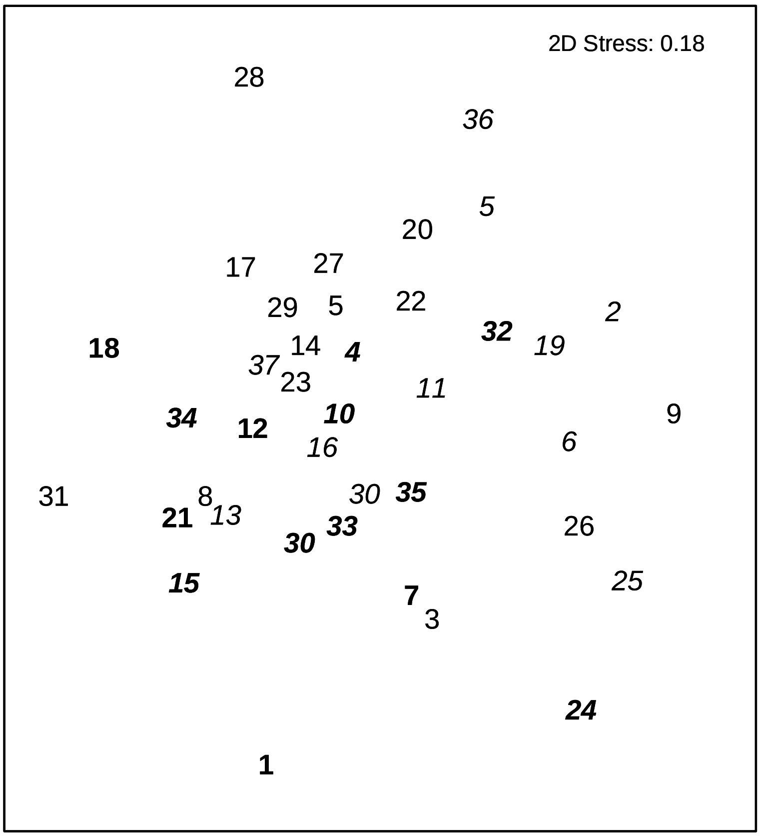

Figure 4. MDS plot comparing fish assemblages sampled in Take (general use, habitat protection, habitat protection restricted) and *No take* (*italic*; special purpose, sanctuary) zones in all sites at Batemans Marine Park. **Bold** indicates 10 m sites.

3.2 Invertebrates and cryptic fish

Fifty two species of mobile macro-invertebrates and cryptic fish were counted during the surveys between 2005-07. Macro-invertebrates were comprised by 17 species of molluscs, 14 species of echinoderms, and 7 crustaceans. In addition the large ascidian *Herdmania momus* was also included because of its overall contribution to the invertebrate biomass on reefs in this region. Overall, fourteen species of cryptic fish were found throughout the surveys. These were relatively rare, accounting for only a small proportion of species encountered, and only two species were recorded in 2007.

Despite year to year variation that may be attributed to site variation between surveys, there was a good balance in the diversity of invertebrates and cryptic fish between Take and No take zones (Fig. 5a) suggesting the chosen sanctuary zones were broadly representative of the diversity of this region. Abundances of inverebrates and cryptic fish species at each site have been previously reported for 2005 and 2006 (Barrett *et al.*, 2007) and for 2007 are shown here in Appendix 2.

The total abundance of invertebrates and cryptic fish differed substantially between years (Fig. 5b), again presumably due primarily to site related differences, however, like the diversity patterns, there was a good overall balance between Take and No-take zones in all years. The most abundant invertebrate species was *Centrostephanus rodgersii* (Long spine urchin), which numerically dominated the assemblages at many sites. Other abundant species were *Astralium* spp. (Turban shell), *Heliocidaris* spp. (common urchins), *Herdmania momus* (Red throat ascidian) and *Turbo torquatus* (Turbo shell).

In general, the most abundant macro-invertebrates were evenly distributed between Take and No-take areas (Fig. 6 a-c), suggesting the sanctuary zones were broadly representative of the region. Special interest species, such as *Turbo* spp., (Turbo shell), *Haliotis rubra* (Blacklip abalone) and *Jasus* spp. (Rock lobster) were generally rare (Fig. 6 d-f), though were distributed relatively evenly between levels of protection. Lobsters were an exception as these were only encountered at a limited number of sites (hence the high error values), and the pattern shown here reflects more chance with respect to sites chosen rather than any protection related pattern in zone positioning.

The MDS plot of site to site variation in invertebrate assemblages indicated there were generally no significant differences were evident between Take and No Take zones and between assemblages at 5 m and 10 m depths (Fig. 7). The exception to this were some sanctuary zone sites at the southern end of the Park, Binji Point (sites 24 and 25) and Bogolola Point (site 32) which grouped as outliers and were characterised by having the lowest densities of *C. rodgersii and Astralium,* which gave greater leverage to the presence of less common species that differed between these sites.

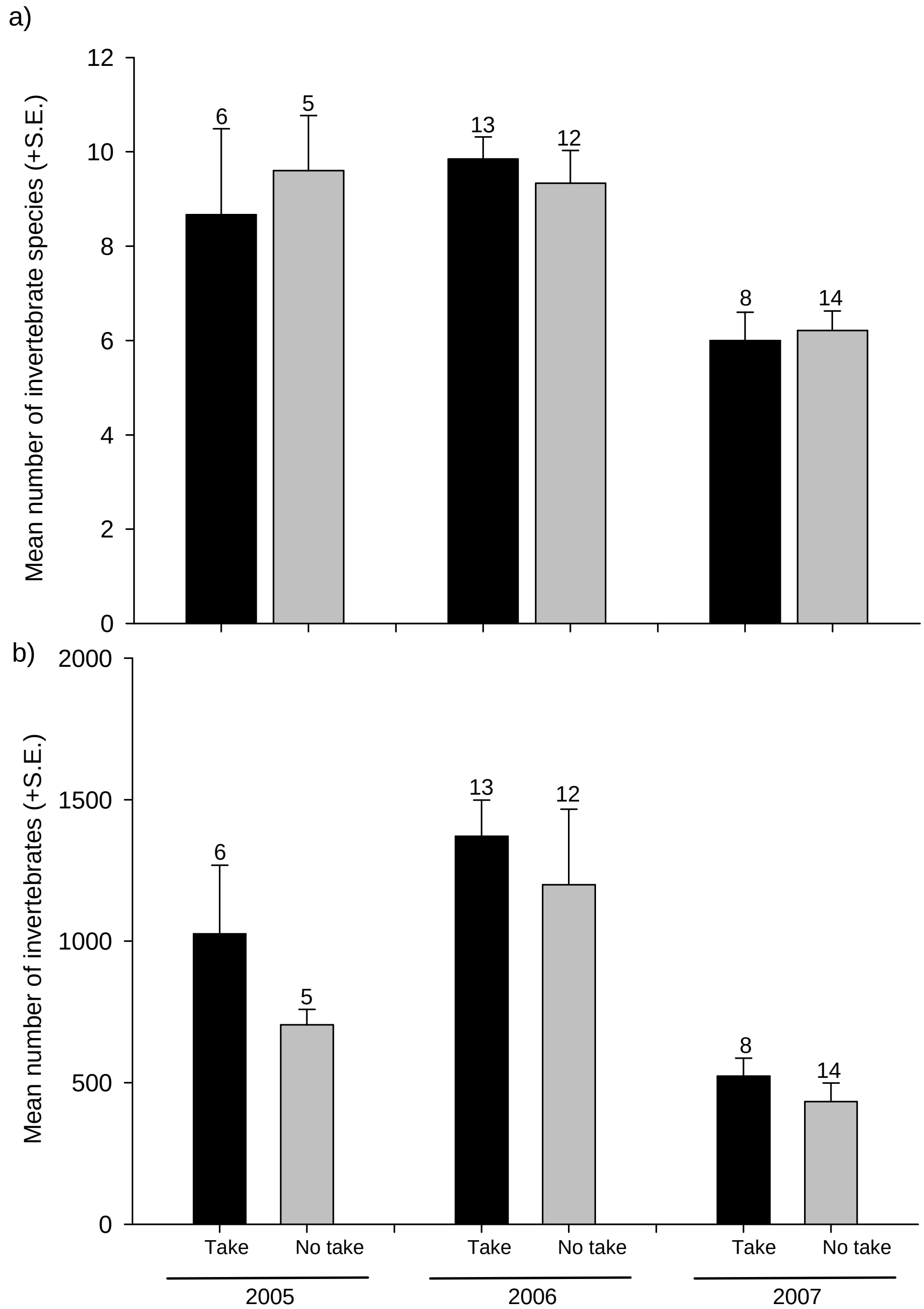

Figure 5. Mean diversity (a) and abundance (b) of invertebrates and cryptic fish sampled at Batemans Marine Park, in Take (general use, habitat protection, habitat protection restricted) and No take (special purpose, sanctuary) zones. Numbers of sites sampled (n) are above each bar.

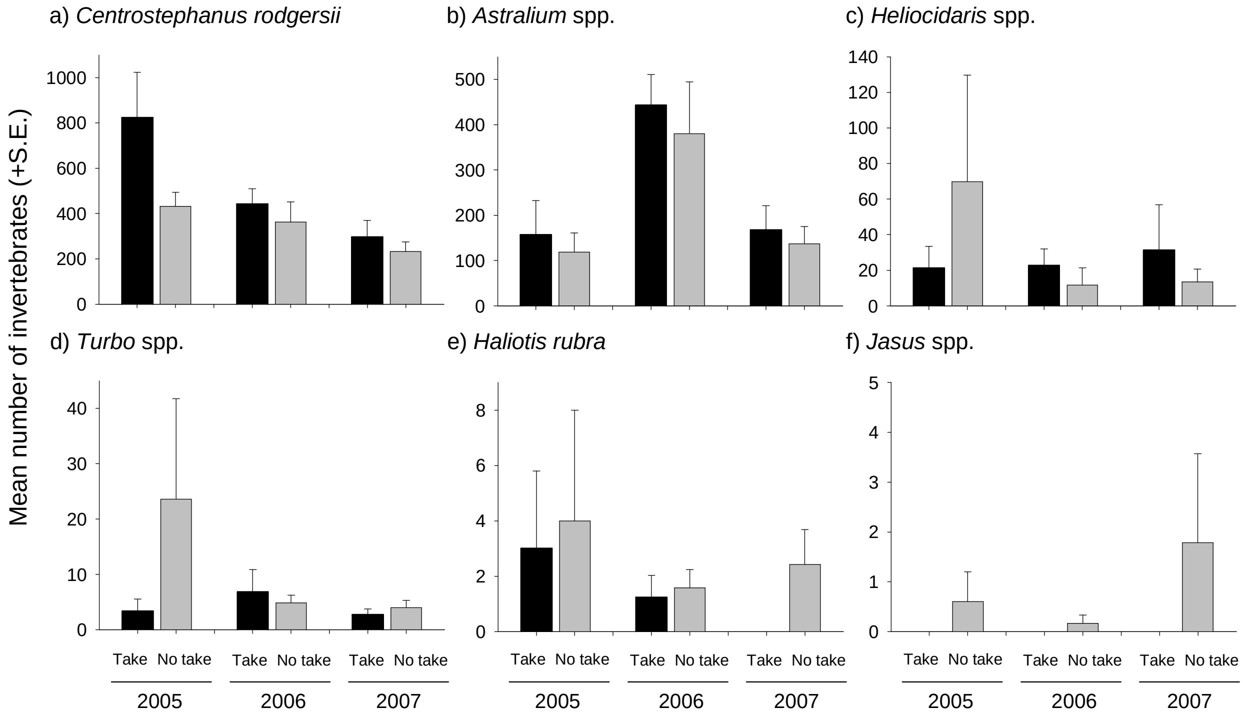

Figure 6. Mean abundance of most abundant (a-c) and special interest (d-f) invertebrates sampled at Batemans Marine Park in Take (general use, habitat protection, habitat protection restricted) and No take (special purpose, sanctuary) zones. Numbers of sites sampled are shown in Fig. 5.

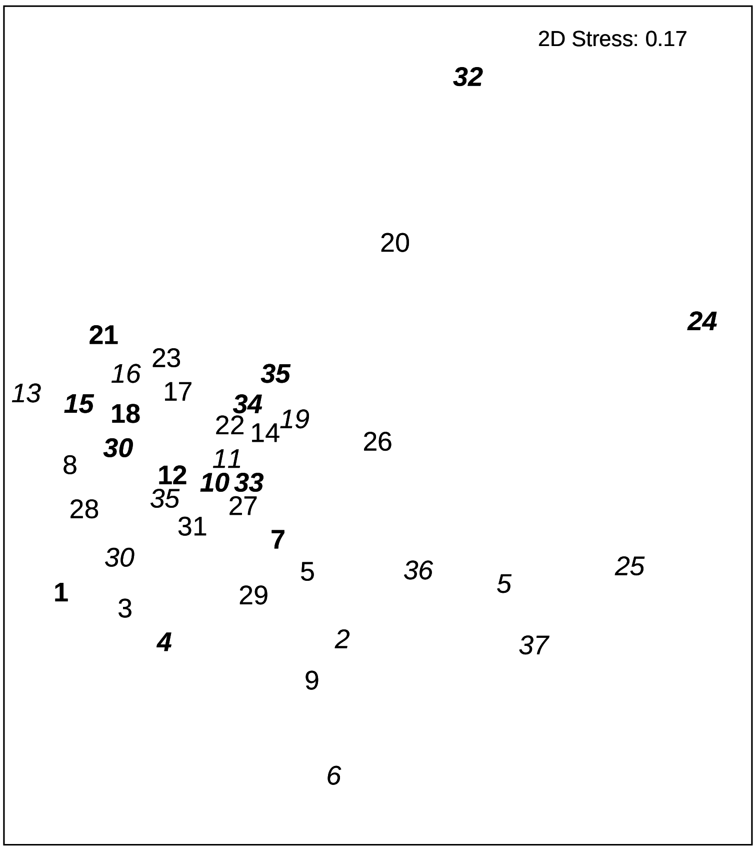

Figure 7. MDS plot comparing invertebrate and cryptic fish assemblages sampled in Take (general use, habitat protection, habitat protection restricted) and *No take* (*italic*; special purpose, sanctuary) zones in all sites at Batemans Marine Park. **Bold** indicates 10 m sites.

3.3 Algae

Over sixty species of algae were sampled during the three surveys, and while more species were present, identifications were restricted to species or genus that could be identified in the field. In 2007, they comprised 22 species of brown algae, 7 species of red algae and 5 species of green algae. The number of species present was relatively similar throughout 2005-2007 and no overall differences between Take and No-take zones were evident (Fig. 8) suggesting that as with the fish and invertebrates, the sanctuary zones and sites broadly reflect the overall diversity of algae found within this region. The cover of algal species, encrusting invertebrates and different substrata surveyed at each site have been previously reported for 2005 and 2006 (Barrett *et al.*, 2007) and for 2007 are shown here in Appendix 3.

The overall most abundant algae with respect to cover were the crustose corraline and encrusting Peysionelia species, while of the foliose algal species *Ecklonia radiata* (common kelp) was by far the most common species (Fig. 9 a-c). Other common foliose algae included *Phyllospora comosa* and *Sargassum* spp. (brown canopy forming algae; Fig. 9 d-e). The distribution of species was relatively consistent between levels of protection and years and indicated a good match between sites chosen to contrast future protection related changes.

Extensive barren zones characterised much of the region, covering an average of approximately 50% of the area surveyed (Fig. 9 f).

The MDS plot of site relationships based on algae assemblages suggested there were no significant differences between sites in Take and No take zones and between assemblages at 5 m and 10 m depths (Fig. 10).

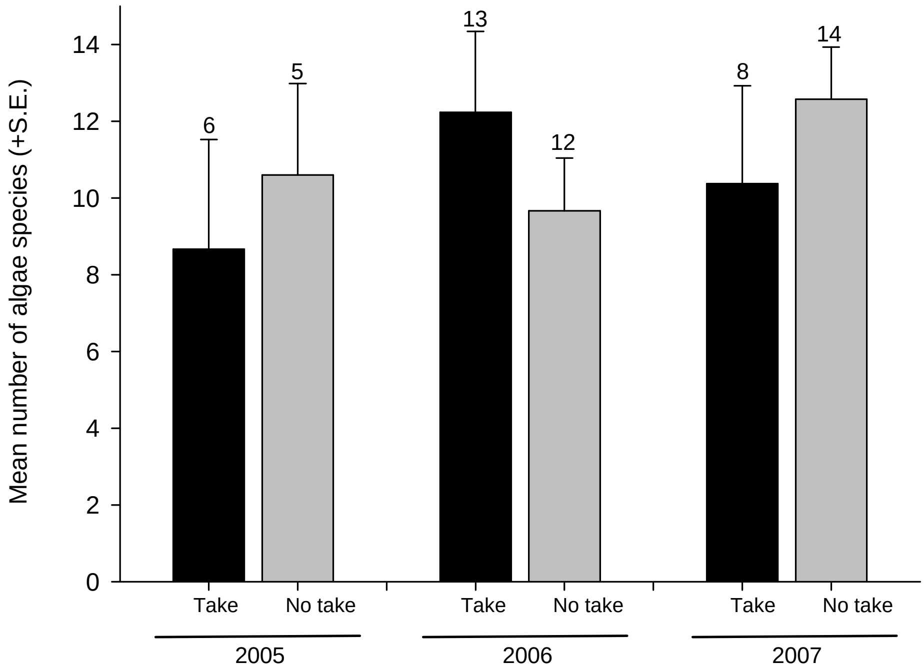

Figure 8. Mean diversity of algae in Batemans Marine Park, in Take (general use, habitat protection, habitat protection restricted) and No take (special purpose, sanctuary) zones. Numbers of sites sampled (n) are above each bar.

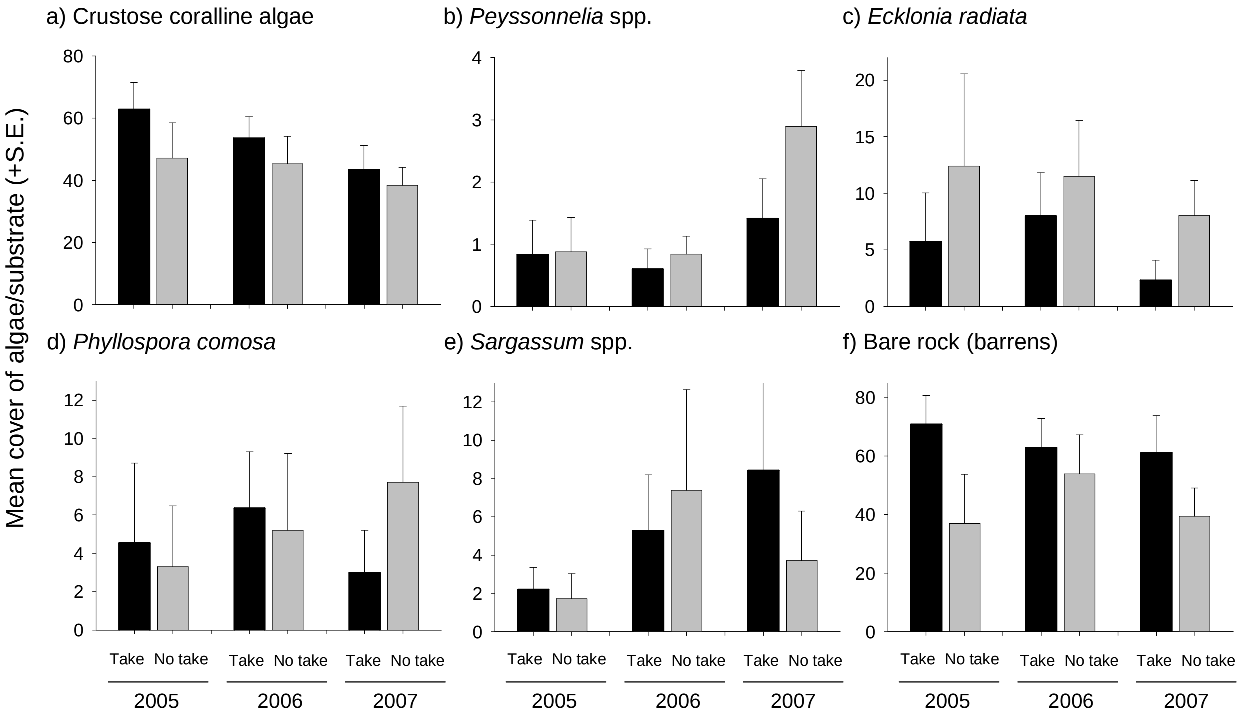

Figure 9. Mean cover of algae with the largest cover (a-e) and bare rock cover in barrens (f) in Batemans Marine Park in Take (general use, habitat protection, habitat protection restricted) and No take (special purpose, sanctuary) zones. Numbers of sites sampled are in Fig. 8.

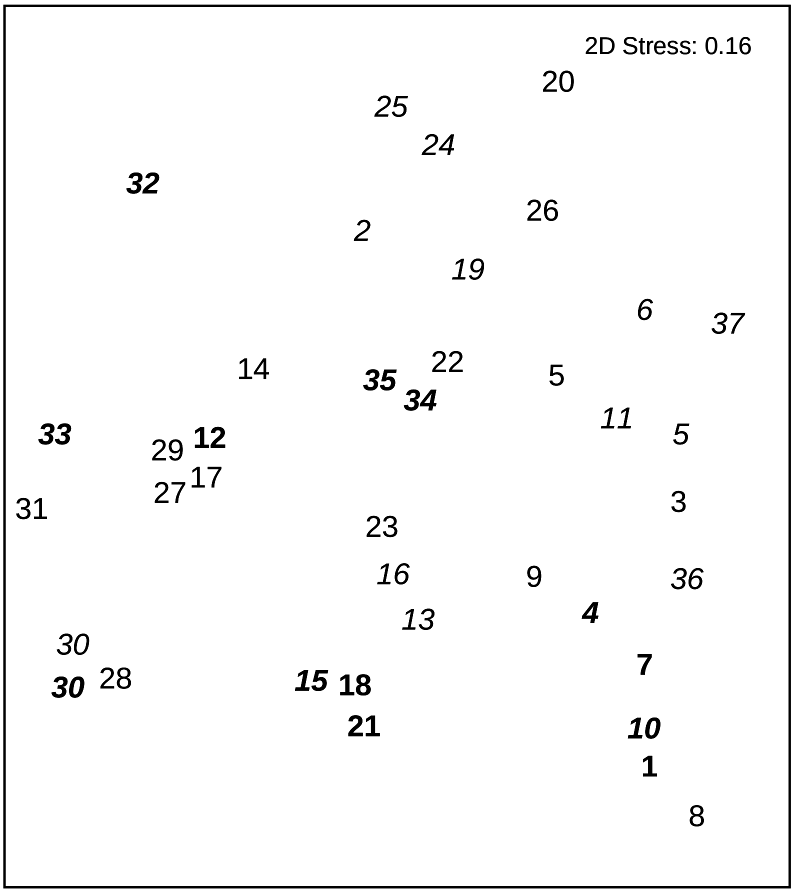

Figure 10. MDS plot comparing algae assemblages sampled in Take (general use, habitat protection, habitat protection restricted) and *No take* (*italic*; special purpose, sanctuary) zones in all sites at Batemans Marine Park. **Bold** indicates 10 m sites.

4. Discussion

The surveys described in this study provide a quantitative description of the reef fish, large mobile invertebrates and cover forming algae and animals of the shallow rocky reefs within the Batemans Marine Park.

One of the most often encountered difficulties in establishing such studies is the inability to find suitable matching control sites for the areas that are given full or partial protection. The response of species in each level of protection needs to be assessed relative to changes in fished controls. The other component that contributes to robustness of design is the degree of replication at the site level. From previous experience, biologically meaningful change in the abundance of common species should be detected with replication involving approximately six sites per "treatment" (Take and No take; Edgar and Barrett, 1997). This is an optimal compromise between cost and the contribution that extra sites can make to the power of any tests examining the magnitude of change. In the case of the BMP additional sites are beneficial, not only to increase power, but also to obtain replication where possible within individual zones so that the performance of each can be assessed through time.

The BMP is complex as it consists of a series of 'pocket' sanctuary zones. In order to be able detect area specific effects, the baseline surveys attempted to include at least one site in every sanctuary zone containing rocky reef habitat. One exception is the small sanctuary zone located at South East Montague Island that was excluded due to last minute boundary changes. For every sanctuary site, an attempt was made to survey a nearby reference reef located in a 'Take' zone. Despite best attempts there is some discrepancy in the south of the park as the Mullimburra Point (encompassing Bingi Bingi Point) and Bogola Point sanctuary areas do not have proximal reference sites and this was apparent in invertebrate assemblage data where these locations formed as outliers in the data. Besides these issues, the overall BMP survey design appears to be well matched as the fish, invertebrate and algal assemblage data are relatively homogenous between management zones. This suggests that the experimental design should be sufficiently robust for a before-after-control-impact (BACI) approach to detect any changes in sub-littoral ecological communites following protection.

With respect to the timing and extent of changes following protection, it is anticipated from our previous Tasmanian work (Edgar and Barrett 1997, 1999; Barrett *et al*., 2007) and national and international studies (Carter and Sedberry, 1997 in Ward *et al.*, 2001), that any biologically meaningful shifts after fishing closure occurs will take a minimum of 2-4 years to become apparent. Density differences are maximised between six and eight years following protection, and monitoring should continue for at least ten years (Ward *et al.*, 2001). This time scale should be sufficient for species that have either pulse or episodic recruitment events to settle and establish and should also be long enough to account for variation between recruitment years.

The type and magnitude of ecosystem shifts following protection from fishing is difficult to predict. It is anticipated that closures to fishing will result in a shift in abundance in some species. This will not necessarily correspond to an increase in abundance for all species in the no take zones. For example some species may survive better in fished areas as they experience less predation pressure. Similarly, there is the potential for some territorial species to increase in size, leading to larger territory size that will result in an overall reduction in numbers over a given area. In particular the Murramarang special purpose zone is of interest as potentially natural mortality of abalone may increase due to protection of predators from fishing while fishing mortality will remain similar to other un-protected sites.

The 2007 survey plan was to create new sites in two sanctuary zones (North Head and Broulee Is) that currently had only one site (due to boundary changes), and to replicate as many of the 2005/06 sites as possible in the time frame budget for. While poor weather and local area staff availability restricted the number of sites able to be repeated in 2007, the overall number surveyed (22) was more than sufficient to provide a robust baseline from which future surveys can be planned. As the MPA zones had only recently been declared and protected at the time of the 2007 survey, the sites included in the 2005-07 surveys could essentially be treated as "before" sites in any long-term study of changes following protection within the Batemans Bay Park. Depending on funding availability, ongoing studies could include a longer survey period (approximately 3 weeks) to replicate all the sites currently surveyed within the MPA, giving the maximum information on zone by zone changes across the park. Alernatively, on the basis of existing site level information, a subset of sites could be chosen as the core component for annual replication to describe the time series of change and understand local patterns of annual variability. The full set could be surveyed at greater periods (5 years) to give more power and increased confidence to trends observed within the smaller subset of sites.

5. Conclusions

With minor adjustments, the current experimental design should detect any significant species or assemblage level shifts that may develop following protection. This includes changes in abundance and diversity of fish and invertebrates and changes in algal cover and diversity. The selection of over six sites within each treatment should ensure all biologically meaningful changes are detected and described. Continuing surveys at annual intervals are highly recommended to establish time series data and to allow trends through time to be differentiated from chance fluctuations. Once trends in abundance of key species stabilise, then the frequency of monitoring can decrease. Changes in cover of macroalgae are predicted to take considerably longer to express themselves than changes in populations of fish and invertebrates. If insufficient funding is available for the full monitoring program in any year, we recommend that assessment of macroalgae be omitted rather than data on fish and invertebrate assemblages at the full range of sites.

6. Acknowledgments

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Appendix 1. Fish abundances recorded during Bateman Bay surveys December 2007.

Species	Depth Common Name/Site	5 3	5 5	5 6	5 11	5 13	5 16	5 19	5 20	5 22	5 23	5 25	5 26	5 36	5 37	10 1	10 10	10 15	10 18	10 21	10 24	10 34	10 35	Total
Acanthistius ocellatus	Eastern wirrah	1	0	2	0	0	0	0	0	0	0	0	1	0	0	6	0	0	0	0	1	0	0	11
Achoerodus viridis	Eastern blue groper	8	2	11	8	6	10	2	9	3	2	40	2	0	3	13	0	7	0	2	17	2	13	160
Anoplocapros inermis	Eastern smooth boxfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	3
Aracana aurita	Shaw's cowfish	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Aspasmogaster costata	Eastern clingfish	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	3
Atypichthys strigatus	Mado sweep	1303	170	302	260	119	230	55	45	113	29	295	308	159	47	1793	306	49	0	195	628	24	338	6768
Aulopus purpurissatus	Sergeant baker	0	1	0	0	0	0	0	1	1	0	0	0	1	0	8	0	0	0	0	0	0	0	12
Austrolabrus maculatus	Black-spotted wrasse	0	1	3	0	2	0	0	3	0	3	10	3	0	2	4	0	0	0	0	5	0	2	38
Bovichtus angustifrons	Dragonet	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Brachaluteres jacksonianus	Pygmy leatherjacket	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Caranx dentex	Silver trevally	2	0	0	0	0	0	0	0	0	0	2	0	0	0	10	0	121	0	1	0	2	0	138
Cheilodactylus fuscus	Red morwong	6	12	4	7	17	35	5	16	10	0	5	0	11	12	19	4	15	0	2	22	7	29	238
Cheilodactylus spectabilis	Banded morwong	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Chromis hypsilepis	One-spot puller	167	4	0	6	97	210	0	0	0	49	1	0	0	559	630	3	706	79	950	0	5	409	3875
Chrysophrys auratus	Snapper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	11	0	0	14
Cnidoglanis macrocephalus	Estuary catfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Coris picta	Comb wrasse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	1	0	0	0	0	0	0	7
Coris sandageri	King wrasse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Crinodus lophodon	Rock cale	21	12	17	28	16	19	4	0	3	3	103	10	2	13	3	2	24	3	0	9	2	11	305
Dasyatis brevicaudata	Smooth stingray	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	4
Dinolestes lewini	Long-fin pike	0	0	96	17	3	0	0	3	3	0	38	0	2	0	1	0	2	4	44	136	0	0	349
Enoplosus armatus	Old wife	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0	0	4	0	0	12
Eubalichthys bucephalus	Black reef-leatherjacket	0	0	1	1	0	0	0	0	0	0	0	0	0	0	5	0	1	5	0	0	0	4	17
Eubalichthys mosaicus	Mosaic leatherjacket	2	0	0	0	0	0	0	0	0	0	4	0	0	0	2	0	0	0	0	0	0	1	9
Eupetrichthys angustipes	Snake-skin wrasse	0	0	0	0	7	0	2	3	1	4	0	1	0	11	5	0	0	0	0	2	2	2	40
Girella elevata	Rock blackfish	0	0	0	0	0	0	0	0	0	0	31	0	0	0	0	0	0	0	0	0	0	0	31
Girella tricuspidata	Luderick	3	0	0	0	4	0	0	0	0	0	0	12	0	14	0	0	0	0	0	0	0	0	33
Girella zebra	Zebra fish	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3	0	1	0	0	0	5
Gymnothorax prasinus	Green moray	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	5
Heterodontus portusjacksoni	Port Jackson shark	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	1	4
Hypoplectrodes maccullochi	Half-banded seaperch	1	0	0	0	0	0	0	0	0	6	0	0	0	0	18	0	1	1	13	0	22	4	66
Hypoplectrodes nigrorubrum	Banded seaperch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Kyphosus sydneyanus	Silver drummer	0	0	0	0	13	0	0	0	0	0	0	10	0	0	0	3	0	0	0	0	0	0	26
Latridopsis forsteri	Bastard trumpeter	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	3
Lotella rhacina	Beardie	0	0	0	1	0	0	0	0	0	0	1	0	0	0	3	0	0	0	1	0	0	0	6

Appendix 1. cont. Fish abundances recorded during Bateman Bay surveys December 2007.

	Depth	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**Total**
Species	**Common Name/Site**	**3**	**5**	**6**	**11**	**13**	**16**	**19**	**20**	**22**	**23**	**25**	**26**	**36**	**37**	**1**	**10**	**15**	**18**	**21**	**24**	**34**	**35**	
Mecaenichthys immaculatus	Immaculate damsel	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	3
Meuschenia flavolineata	Yellow-stripe leatherjacket	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
Meuschenia freycineti	Six-spine leatherjacket	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	3
Meuschenia scaber	Velvet leatherjacket	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Myliobatis australis	Eagle ray	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
Nelusetta ayraudi	Chinaman leatherjacket	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Nemadactylus douglasi	Blue morwong	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	3
Notolabrus gymnogenis	Crimson-banded wrasse	10	11	9	24	25	12	12	24	9	41	41	13	7	21	14	29	9	15	14	19	20	23	402
Nototodarus gouldie	Arrow Squid	0	0	0	0	0	0	0	0	0	0	28	0	0	0	0	0	0	0	0	0	0	0	28
Odax acroptilus	Rainbow cale	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3
Odax cyanomelas	Herring cale	1	5	11	19	12	7	0	5	16	5	10	0	1	14	0	1	0	0	0	10	14	15	146
Ophthalmolepis lineolata	Maori wrasse	0	5	0	78	23	0	30	38	7	46	9	10	5	31	51	25	5	4	13	20	48	59	507
Orectolobus maculatus	Spotted wobbegong	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Orectolobus ornatus	Ornate Wobbegong	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	3
Parma microlepis	White-ear	38	28	23	34	54	39	10	3	47	90	23	2	19	35	58	55	35	47	70	14	28	33	785
Parma polylepis	Banded parma	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Parma unifasciata	Girdled parma	0	0	0	6	5	2	0	12	5	4	0	0	0	9	1	0	0	0	0	3	2	0	49
Parupeneus signatus	Blackspot goatfish	0	0	0	1	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	4
Pempheris compressa	Small-scale bullseye	3	0	0	0	0	0	0	8	0	0	0	0	0	0	169	0	0	0	0	0	0	0	180
Pempheris multiradiata	Common bullseye	0	148	73	1	2	0	0	0	55	9	0	0	21	0	885	0	0	23	8	78	0	0	1303
Pictilabrus laticlavius	Senator wrasse	3	10	11	4	10	3	16	5	6	3	10	3	1	11	0	0	0	0	0	14	7	9	126
Pseudolabrus guntheri	Gunthers wrasse	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pseudolabrus psittaculus	Rosy wrasse	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	2
Schuettea scalaripinnis	Eastern pomfret	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	15
Scorpaena cardinalis	Red rock cod	0	1	0	0	1	0	1	2	0	0	0	0	0	0	1	0	0	0	0	0	2	1	9
Scorpis aequipinnis	Sea sweep	0	0	0	5	0	0	1	0	0	0	0	0	0	0	0	0	74	0	0	0	0	0	80
Scorpis lineolata	Silver sweep	18	24	11	5	4	33	0	15	119	18	282	336	4	38	105	14	13	125	45	145	0	13	1367
Sepia apama	Giant cuttle	1	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	4
Suezichthys aylingi	Crimson cleaner fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3
Tetractenos glaber	Smooth toadfish	0	0	2	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	6
Threpterius maculosus	Kelpfish	6	0	0	10	0	5	6	0	1	0	99	10	0	0	0	0	1	0	0	5	0	1	144
Torquigener pleurogramma	Banded toadfish	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	3
Trachinops taeniatus	Eastern hulafish	24	40	143	89	239	437	0	159	118	391	21	0	70	408	570	548	337	681	687	17	64	35	5078
Trachurus novaezelandiae	Yellow-tail scad	17	0	0	0	0	0	0	0	0	0	0	0	10	0	1050	0	0	15	0	0	4	0	1096
Trygonoptera testacea	Common stingaree	0	1	0	0	0	0	1	1	0	1	0	2	0	0	0	0	3	1	0	5	0	0	15
Trygonorrhina fasciata	Fiddler ray	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Upeneichthys lineatus	Blue-lined goatfish	1	0	0	0	0	0	0	1	0	0	0	0	1	2	17	0	0	0	0	1	0	0	23
Species richness (species per site)		**21**	**19**	**19**	**21**	**21**	**14**	**16**	**23**	**19**	**18**	**27**	**17**	**16**	**19**	**37**	**16**	**22**	**15**	**17**	**26**	**21**	**24**	
Total species richness (species per 2007 survey)													**72**											

Appendix 2. Invertebrate and cryptic fish abundances recorded during Bateman Bay surveys in 2007.

	Depth	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**Total**
Species	**Common Name/Site**	**3**	**5**	**6**	**11**	**13**	**16**	**19**	**20**	**22**	**23**	**25**	**26**	**36**	**37**	**1**	**10**	**15**	**18**	**21**	**24**	**34**	**35**	
Cryptic Fishes																								
Gymnothorax prasinus	Green moray	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3
Scorpaena cardinalis	Red rock cod	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Molluscs																								
Astralium tentoriformis	Turban shell	97	63	3	126	491	252	49	96	272	267	0	74	275	37	42	294	93	34	460	2	111	126	3264
Cabestana spengleri	Triton shell	8	0	1	0	0	0	0	0	0	0	25	1	0	1	0	0	0	0	13	1	2	3	55
Cymbiola magnifica	Magnificent volute	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Dicathais orbita	Dog whelk	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Haliotis rubra	Blacklip abalone	0	3	6	0	0	0	0	0	0	0	16	0	0	8	0	0	0	0	0	1	0	0	34
Octopus spp.	Octopus	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
Turbo undulatus	Periwinkle	3	3	1	4	1	0	6	5	7	1	7	6	0	6	0	0	0	0	0	18	1	9	78
Echinoderms																								
Asterodiscides truncatus	Seastar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Cenolia trichoptera	Featherstar	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	4
Centrostephanus rodgersii	Long-spine urchin	587	84	33	326	411	341	175	11	162	140	83	183	330	99	439	438	505	523	328	5	253	161	5617
Heliocidaris erythrogramma	Common urchin	4	2	0	26	0	0	78	207	4	0	4	33	0	71	0	0	0	0	0	0	0	0	429
Heliocidaris tuberculata	Urchin	2	0	0	0	0	0	0	0	0	0	4	1	0	3	0	0	0	0	0	0	0	0	10
Pentagonaster dubeni	Fire-brick star	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Phyllacanthus parvispinus	Eastern slate-pencil urchin	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	3	0	0	0	0	3	9
Plectaster decanus	Seastar	0	0	0	3	0	2	1	1	0	2	0	0	1	0	0	2	4	4	1	0	0	0	21
Crustaceans																								
Jasus edwardsii	Southern rock lobster	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	25
Pagurid unidentified	Hermit crab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	5	4	0	0	10
Ascidians																								
Herdmania momus	Red-throat ascidian	2	6	18	21	1	47	16	44	0	36	34	5	0	3	15	11	43	20	36	246	11	75	690
Species richness (species per site)		**8**	**6**	**7**	**7**	**4**	**6**	**7**	**7**	**4**	**5**	**9**	**7**	**3**	**8**	**4**	**5**	**6**	**5**	**8**	**7**	**6**	**6**	
Total species richness (species per 2007 survey)		**20**																						

Appendix 3. Algal percentage cover per site, Batemans Bay surveys 2007.

Depth	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Common Name/Site	**3**	**5**	**6**	**11**	**13**	**16**	**19**	**20**	**22**	**23**	**25**	**26**	**36**	**37**	**1**	**10**	**15**	**18**	**21**	**24**	**34**	**35**
Green Algae																						
Caulerpa cactoides	0	0	0	0	0	0	1.9	1.7	0	0	0	1.0	0	7.6	0	0	0	0	0	0	0	0
Caulerpa flexilis var. muelleri	0	0	0	0	0	0	18.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caulerpa geminata	0	0	0.8	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Codium dimorphum	0	0.5	0	1.3	0	0	0	0	0	0	0.8	0	0	1	0	0	0	0	0	0.2	0.2	0
Codium fragile	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0.3	0	0
Green turf	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0
Brown Algae																						
Acrocarpia paniculata	0	3.4	4.5	15.3	0	0.1	0.7	0	1.1	0	0	0	1.6	5.1	0	0	0	0	0	0	0.6	3.6
Brown turf	0	0	0	0.2	0	0	0	0	0	1.5	0.5	0	0	0	0	0	0	0	0	0	0	0
Colpomenia sinuosa	0	0.5	0.9	0.5	0.1	0	2.3	0.2	0.4	0.5	4.0	4.0	0.2	0	0	0	0	0	0	1	0	0
Cystophora grevillei	0.7	2.4	3.2	0	0	0	0.5	0	0	0	0	0.2	0	0	0	0	0	0	0	0.3	0	0
Cystophora monilifera	0	0	0	0	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cystophora moniliformis	0.8	5.8	0	0	4.1	0	2.5	0	0	0	0	2.9	0	8.1	0	0	0	0	0	0	0	0
Dictyopteris muelleri	0	0	0	0	0	0	0	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dictyota dichotoma	0	0	0	0	0	0.2	4.4	7.8	0.5	0	0	0.2	6.3	0	0	0	1.1	0.2	0.2	0.4	0	0
Dictyota sp.	0	0	0	0	0	0	0	0	0	0	1.2	0	0	0	0	0	0	0	0	0	0	0
Dilophus gunnianus	0	1.2	0	1.1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ecklonia radiata	0	1.1	0	34.9	0	5.4	0	3.3	14.4	0.8	9.9	0	0	21.2	0	0	0	0	0	12.1	0.8	27.0
Encrusting brown algae	16.9	8.8	0.7	6.1	8	10	3.1	1	6.7	19.5	0	4.1	3.3	2.1	5.6	1.6	0	2.6	2	0	9.1	1.8
Halopteris paniculata	0	0.2	2	0	0	2.4	0	0.2	1.2	0	0	0	0	2.1	0	0	0	0	0	0.6	1.6	3.4
Homeostrichus olsenii	2.4	1.1	10.9	0	0	0.4	0.2	9.5	0.9	0	0	0.8	0.8	4.1	0	0	0	0	0	0.8	0	3.6
Lobophora variegata	2.0	0	2.9	2.5	0.1	4.9	2.3	2.2	0	0.3	0	0.4	0	0	0	0	0	0	0	0	1.1	0
Lobospira bicuspidata	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0
Padina spp.	0	0.2	3.4	1.4	0	0.7	7.3	12.6	3.1	0	0.4	0	0	2	0	0	0	0	0	0	0	0
Phyllospora comosa	0.3	13.5	50.6	0.9	0	0	30.1	17.7	5.8	0	3.1	0.1	7.7	0.2	0	0	0	0	0	0.6	1.2	0
Sargassum fallax	0	0	0	0	0	0	0	30.2	0	3.8	8.5	1.7	0	0	0	0	0	0	0	1.2	0	0
Sargassum linearifolium	0	0	0	0	0	0	0	9.5	0	0	4.9	3.9	0	0	0	0	0	0	0	1.8	0	0
Sargassum spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0
Sargassum vestitum	5.3	0	0.2	0	0	0	0	1.3	9.6	1.3	20.9	0.8	0	1.2	0	0	0	0	0	12.0	0	1.2
Sporochnus spp.	0	0.2	0.3	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0
Zonaria spiralis	0	0	0.5	0.7	0	0	1.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0.9
Red Algae																						
Asparagopsis armata	0	0	0	0	0	0	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crustose coralline algae	38.5	46.8	29.3	32.2	76.1	55.1	19.2	7.7	57.4	47.4	1.2	18.0	55.2	26.8	55.0	61.1	60.5	47.9	75.4	7.1	35.1	31.6
Delisea pulchra	0	0.1	0.6	0	0	0	0.2	1.8	0	0	0	0	0	1.9	0	0	0	0	0	0	0	0
Geniculate corallines	10.4	23.3	23.2	27.4	1.1	5.8	13.9	5.6	5.3	0	20.3	16.0	5.8	40.8	1	0	0.7	0	0	19.6	11.3	29.7

Depth	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Common Name/Site	**3**	**5**	**6**	**11**	**13**	**16**	**19**	**20**	**22**	**23**	**25**	**26**	**36**	**37**	**1**	**10**	**15**	**18**	**21**	**24**	**34**	**35**
Peyssonnelia novaehollandiae	0	0	0	0	0	0	0	1.3	0.3	0	0.4	0	0	0.3	0	0	0	0	0	1.2	0	0
Peyssonnelia spp. (flat)	0.2	5.3	4.3	1.9	2.8	0.2	4.7	1.6	1.8	0.9	0.3	5.0	1.3	0	0.2	0.2	0.8	0	0	11.8	1.6	3.4
Phacelocarpus peperocarpus	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
Plocamium angustum	0	0	0	0	0	0	0	3	0	0	0	0	0	12.4	0	0	0	0	0	0	0	0
Plocamium leptophyllum	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0
Turfing red	0	0	0	0	0	0	0	0	0	0	0	0	0	1.9	0	0	4.5	0	0	0	0	0
Other																						
Anemones	2.3	0	0.2	0	0	0	0	0	0	0	0	0	0	0	2.7	0	0	0	0	0	0.1	0
Ascidians	0.1	0	0	0	0	0.1	0	0.4	0	0	2.7	0	0	0	0	0.2	0	0	0	2.5	0	0.5
Bare rock (barrens)	60.0	20.0	10.0	25.1	90.0	73.2	1.2	0	59.8	84.2	0	16.9	60.9	10.0	73.7	83.0	96.8	95.0	99.3	0	58.5	23.7
Bare rock (non - barrens)	6.1	0	0	0	0.8	0	0	0	0.3	0.4	0	0	0	0	0	0.8	0	0	2.8	0	0	0
Barnacles	0.3	0	0	0	0.3	4.6	0	0	0	0	0	0	0	0	8.0	1.3	6.4	1.4	1.7	8.3	0.4	0
Capnella spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.1	0	0	0	0
Cobble	0	0	0	0	0	7.5	0	0	0	2.8	0	0	0	0	0	0	0	5.3	6.2	0	10	0
Erythropodium hicksoni	0	0	0.6	0	0.2	2.3	0	0	0	0	0	0	0	0	0	0	0.3	4.2	2	0	0	0
Filograna implexa	0	0	0	0	3.1	0	0	0	0	2.0	0	0	0	0	0.3	0	0	0	0	1.1	0	0
Gravel	0	0	0	1.2	0	0	0	5.0	0	0	0	0	0	0	0	16.6	0	0	0	0	9.7	0
Herdmania momus	0	0	0.2	0.1	0	0.1	0	0.6	0	0	0.2	0	0.1	0.3	0.1	0.2	0	0.3	0	1.3	0.2	0.1
Hydroids	0	0	0	0	0	0	0	0	0	0	2.8	0	0	0	0	0	0	0	0	0.7	0	3
Mopsea spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0
Mussel spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0
Other bryozoa	0.2	0	0.2	0.3	0	0	0.2	1.1	0	0	12.3	0	0	0	0	0	0	0	1.5	1.1	0	0.4
Other sponges	0	0	0	0.1	0	2.1	0.1	0.3	0	0	3.1	0	0	0	0	1.1	0	4.1	0.4	2.7	0.2	0.2
Pebbles	0	0	0	0	0	0	1.2	0	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyura stolonifera	0	0	0	0	0	0	0	0	0	0	29.0	0	0	0	0	0	0	0	0	0	0	0
Sabellastarte spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0.2	0
Sand	0	43.1	3.1	9.4	0	0.4	20.7	30.8	7.3	13.8	0	54.8	5.0	5.6	22.9	0	4.9	0	1.3	15.3	0	5.1
Silt on reef	0.4	0	0	0	12.2	0	0	0	5	4.8	0	0	0	0	14.8	0	0	0	0	0	0	0
Sponge (encrusting)	1.2	0	4.9	1.1	0	0.6	0.2	0.7	0.5	0.3	29.5	0	0	0.2	0.9	0.4	6	4.9	1.8	7.4	0.6	12.4
Turf/sand matrix	0	0.2	24.4	0	0	3	17.4	20.0	1.2	0	23.3	0	0	6.8	1.1	0	0	1.9	0	20.8	0.5	4.0
Zoanthus spp.	0	0	0	0	0	2.9	0	0	0	0	0	0	0	0	0	8.3	7.1	13.5	2.7	0	0	0
Algal species richness (species per site)	**6**	**13**	**13**	**9**	**14**	**4**	**7**	**13**	**19**	**12**	**5**	**12**	**11**	**5**	**0**	**0**	**1**	**1**	**1**	**14**	**7**	**6**
Total algal species richness (species per 2007 survey)	**32**																					